

FUNDAMENTAL STUDY ON GAS MONITORING IN CELSS

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ABSTRACT

A mass spectrometer and computer system was developed for conducting a fundamental study on gas monitoring in CELSS. Respiration and metabolism of the hamster and photosynthesis of the Spirulina were measured in a combination system consisting of a hamster chamber and a Spirulina cultivator. They are connected through a membrane gas exchanger. Some technical problems were examined.

In the mass spectrometric gas monitoring, a simultaneous multi-sample measurement was developed by employing a rotating exchange valve. Long term precise measurement was obtained by employing an automatic calibration system.

The membrane gas sampling probe proved to be useful for long term measurement. The cultivation rate of the Spirulina was effectively changed by controlling CO₂ and light supply. The experimental results are helpful for improving the hamster-spirulina system.

INTRODUCTION

A fundamental study on gas monitoring in CELSS was performed using a computerized mass spectrometer system. O₂ gas exchange and water consumption are of basic importance in CELSS. N₂ fixation and release are also of concern. Several kinds of organic trace gas vapours, some of which are toxic, should also be monitored./1/

In this work, a mass spectrometer computer system was developed for a basic study on CELSS. A brief description of the measuring system, some measuring results on the hamster and Spirulina system are presented. Also some technical problems will be discussed.

DISCRIPTION OF THE MEASURING SYSTEM

The measuring system is illustrated in Fig. 1. Inlet and outlet gas flows, concentrations and temperatures of the Spirulina cultivator, hamster chamber and fermentors are simultaneously monitored. O₂ uptake \dot{V}_{O_2} and CO₂ production \dot{V}_{CO_2} of the animal (including human), and photosynthetic O₂ production, CO₂ consumption and the related physiological factors are calculated and examined in real time.

Mass Spectrometer-Computer System: The mass spectrometer developed is a compact magnetic type. In ordinary use, O₂, CO₂, Ar, N₂ and H₂O are simultaneously measured by the fixed collectors, CH₄, NH₃ and C₂H₅OH can be measured using extended collectors. The voltage scanning system is available for other trace gas analysis. In ordinary use, changes of 0.005% concentration is measurable in long term monitoring by employing automatic calibration. Sample gas is compared to the reference in each cycle, while changes of 0.05% a day is observed in direct reading of the mass spectrometer./3/4/

Direct gas sampling through a small capillary is conventionally employed. In this case, the response of the output to the change of concentration is as high as 30 to 50 ms in 63% rise with sampling rate of 30 ml/min for dry gases. Such a rapid response is useful in the study of human respiration physiology ./2/

The membrane coated sampling probe shown in Fig.3 is also available. The sampling rate is negligible in this case, while the response is as low as 100 s in rise time of 90%./3/

However, the response may be sufficient for long term gas monitoring.

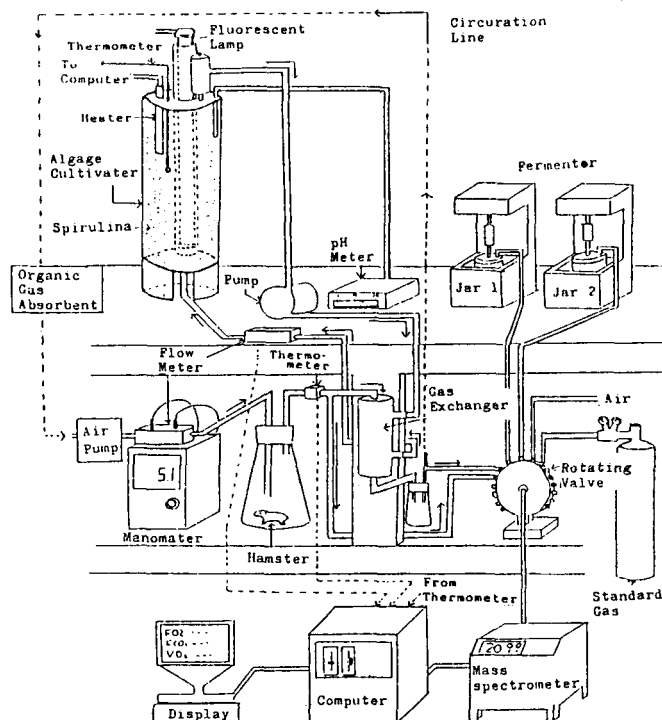


Fig.1. Experimental arrangement. Metabolism and photosynthesis were studied in the hamster and Spirulina system

Computer system: The computer system (CPU: 10/sp, Microeclipse Hard Disk Memory 15 MB) was designed to perform the following functions:

- (1) controlling sample selecting (or exchanging) valve,
- (2) data entry and storage,
- (3) online and offline calculations,
- (4) display of the measured results on CRT, printer and plotter,
- (5) send the measured informations to the culture conditioner,

10 samples can be measured referring to the standard gas by employing the rotating exchange valve.

RESULTS AND DISCUSSION

Measurement of hamster metabolism

The metabolism of the hamster was measured by monitoring inlet and outlet gas concentrations, flow and temperatures. The measured results, FO_2 , FCO_2 , VO_2 , VCO_2 and RQ are shown in Fig.2, A-C and carbohydrate(CHO) and FAT consumption and metabolic energy production are in Fig.3, A-E. The chinese hamster tested was 34.5g weight and $\dot{V}O_2$ was 2.25 ml/min (0.065 ml/g min) in average for an hour. Instantaneous $\dot{V}O_2$ varied from 1.32 to 3.14 ml/min according to the state of activity. The washout time constant of the hamster chamber is 2.7 min. The same kind of measurement is shown in Fig.4. This latter measurement was performed by employing a membrane sampling probe. The sampling rate is almost neglectible comparing to the ordinary capillary probe. This probe is also available for the direct sampling of dissolved gases.

Combination of hamster chamber and Spirulina cultivator

The exhaust gas from the hamster chamber and the water diluted gas in the Spirulina cultivator are exchanged through the membrane gas exchanger. FO_2 , FCO_2 and FN_2 were continuously measured at the inlets and outlets of the hamster chamber and the gas exchanger. The result is shown in Fig.5. The extreme change in concentration at the outlet of the hamster chamber (inlet of the gas exchanger) was stabilized by the buffer effect of the water broth in the Spirulina cultivator. In this case, oxygen production rate (activity of photosynthesis) was improved to 0.4 ml/min, for a liter of the broth, by supplying expired CO_2 of the hamster, from 0.08 ml/min/1 liter broth 0.08 ml/min/1 liter was observed for the room air supply.

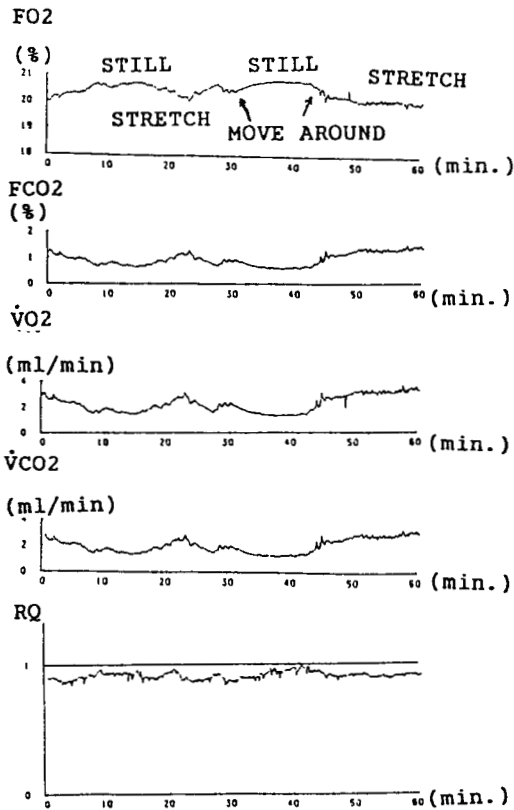


Fig.2. Continuous measurement of FO₂, FCO₂, VO₂, VCO₂ and RQ. The measurement was performed by employing the ordinary capillary probe.

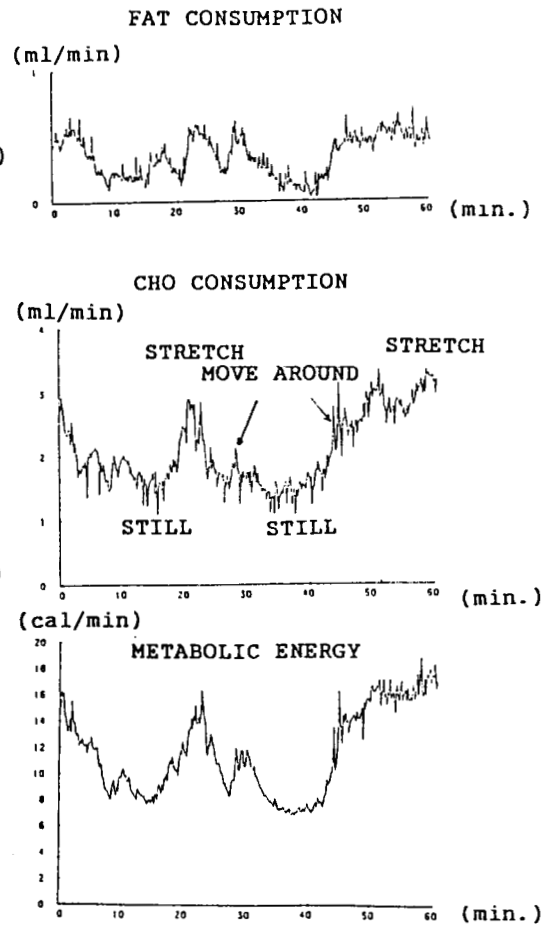


Fig.3. Simultaneous measurement of metabolic factor.

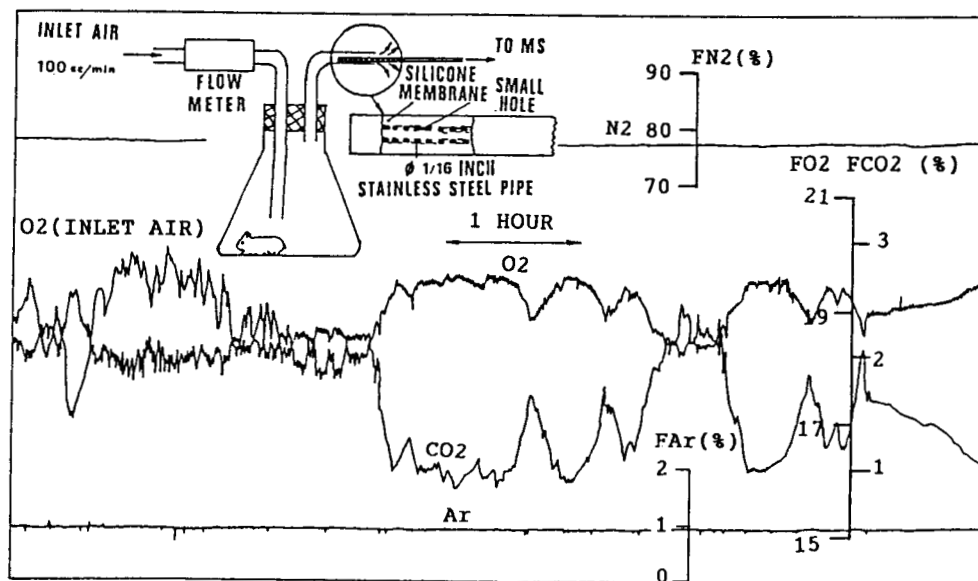


Fig.4. Over night monitoring of the exhaled gas concentration from the hamster chamber. The measurement was performed by employing a silicone membrane probe.

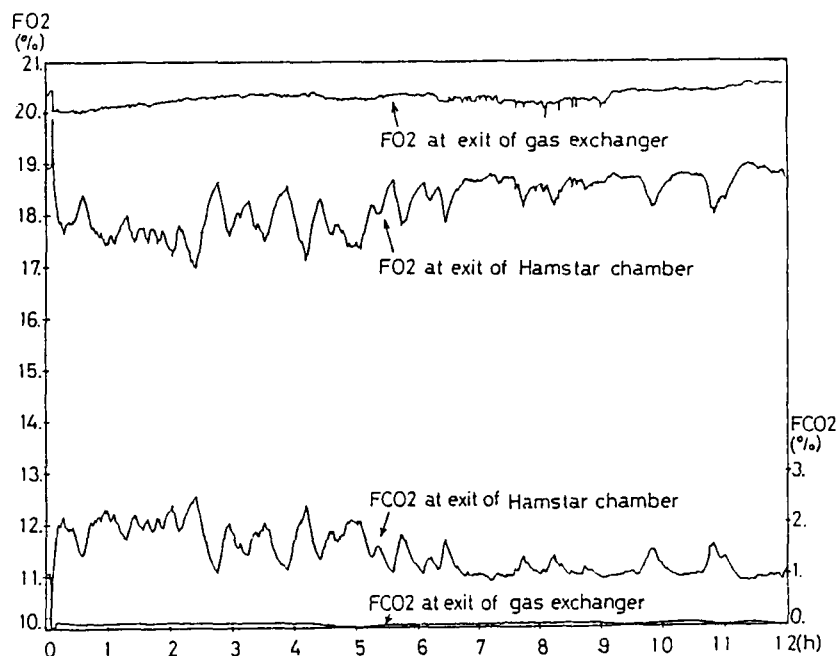


Fig.5. Continuous measurement of gas exchange in the hamster and Spirulina system. The inlet and outlet gas concentrations of hamster chamber and the gas exchanges of Spirulina system were simultaneously measured.

Considerable improvement of O_2 generation was observed by supplying expired CO_2 instead of room air. O_2 generation is, to some extent, controlled by the rate of supplied CO_2 . When lights were completely turned off, O_2 output completely ceased in 90 min. This lag time may be equivalent to the washout time of the Spirulina cultivator itself. Concerning the mass spectrometric measurement, the multi-gas sampling system and the automatic calibration proved to be useful for long term precise gas monitoring in CELSS. However, this method is possible to be employed for the ordinary capillary sampling probe, and a considerable sampling rate is needed (at least 10ml/min) in the completely closed small size simulation system, the membrane probe may be more useful because of its negligible small sampling rate. Further technical improvement, however, is needed to make it practical. The considerations mentioned will help us to improve the design and control of the hamster-spirulina system.

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